



Advanced Pumped Storage

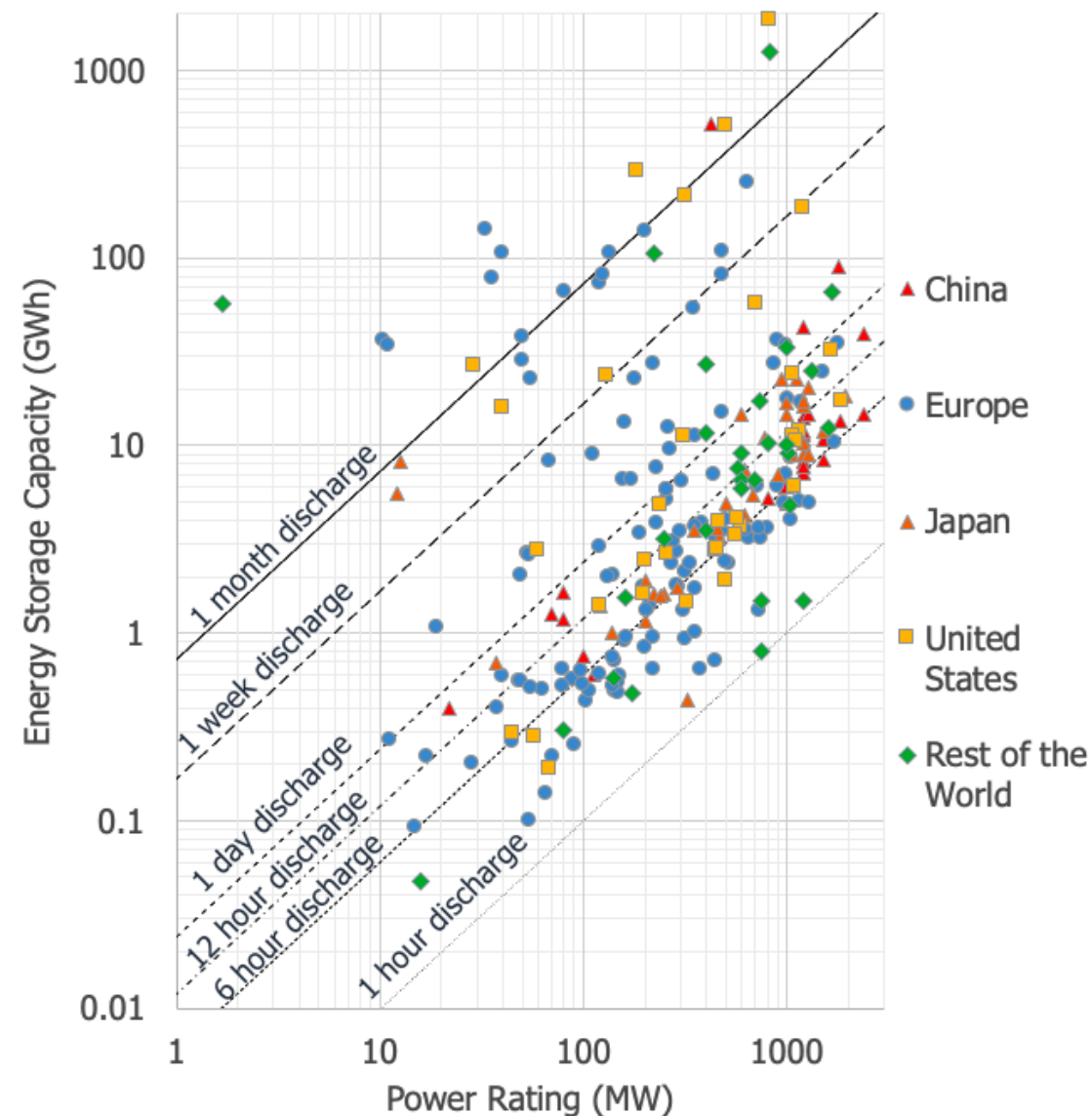
DOE Long Duration Energy Storage Workshop, March 2021



GE Renewable Energy

Scale & duration of PSH

- Current storage volume of PHS : **9,000+ GWh** (batteries ~7-8 GWh).
- **40 countries with PHS**
- Vast majority of pumped storage stations have a discharge **capacity above 1 GWh**, and duration **longer than 6 hours** (up to seasonal storage).
- This plot visualizes the estimated discharge durations relative to installed capacity and energy storage capacity for some 250 pumped storage stations currently in operation (source IHA).



Global Blackouts / near misses

Hydro and PHS first line of defense to keep lights on

UK

9 August 2019

- Heat wave + shutdown of generation assets (1,378 MW from gas and offshore wind) + curtailment of power lines leading to partial blackout
- 1M people without electricity
- Frequency balance restored by combination of load shedding + **running up of PHS to ~1GW**

EUROPE

4 November 2006

- Partial blackout of European grid (5 countries / 15 million households)
- Rolling, full blackout prevented (mainly) by hydro (**5 GW injected**, within **30 minutes** + automatic shedding of **1.6 GW of pumping**)

USA

14 /15 August 2020

- Combination of heatwave driving high demand, and very low wind generation and generator outages,
- emergency conditions in CAISO leading to intentional blackouts for ~ 2 million residents
- 3 GW of PHS to limit shortfall and Hydro providing most of Ancillary Services

AUSTRALIA

8 February 2017

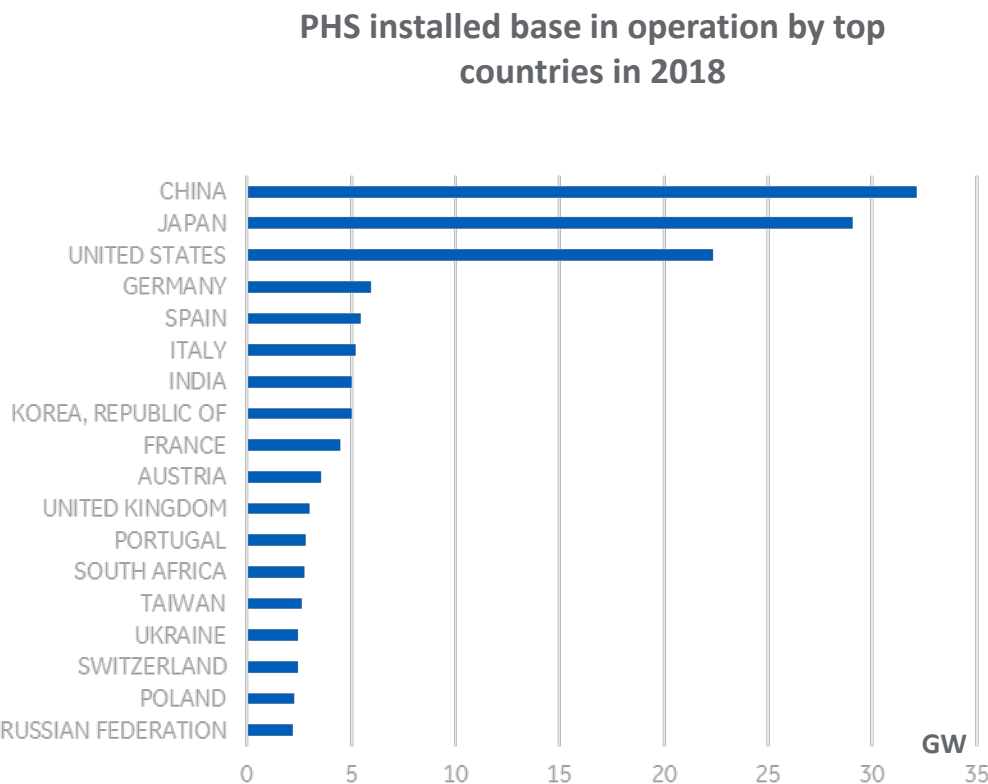
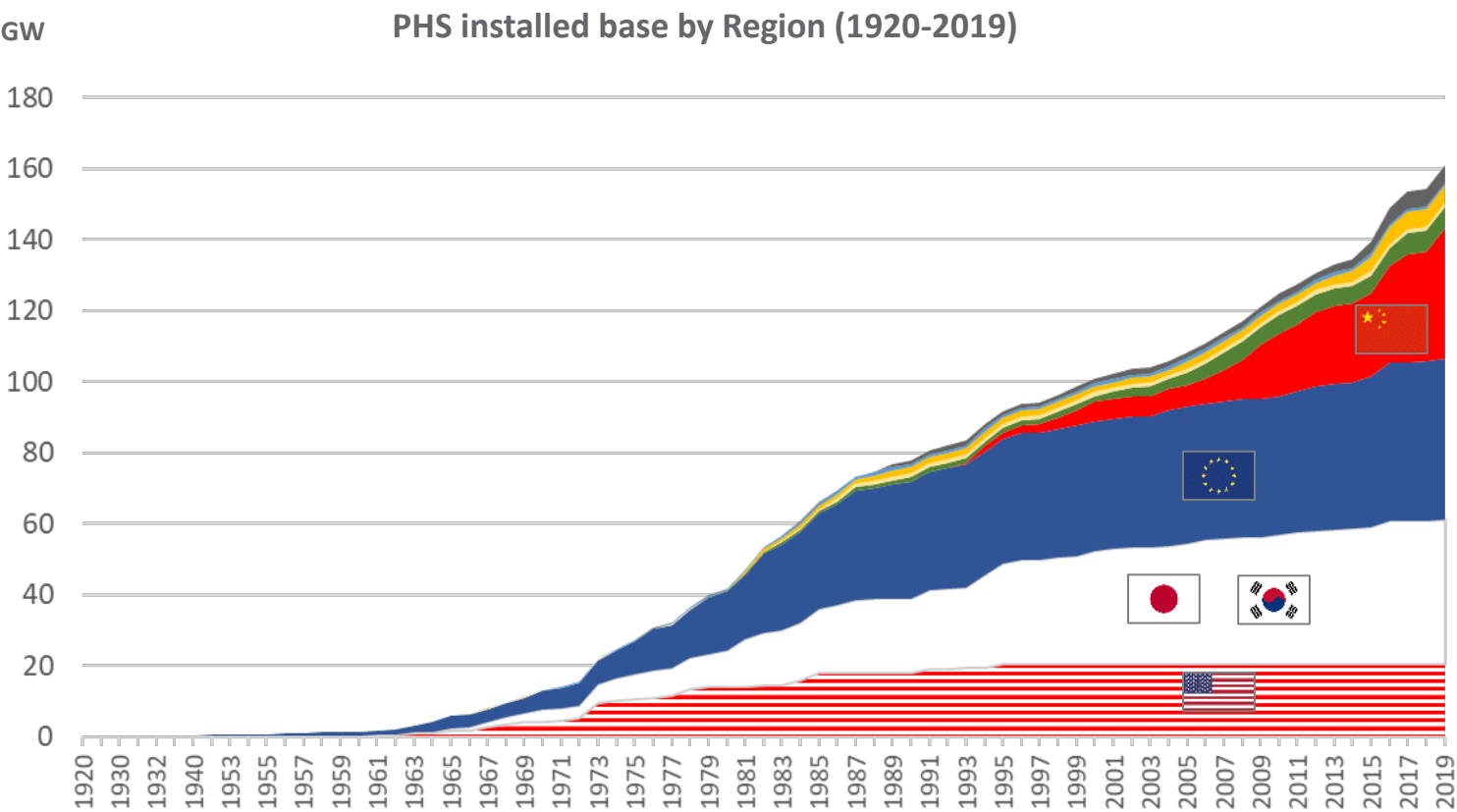
- Load shedding in South Australia on one of the hottest days of the year with low wind production and thermal outages.
- Production shortfall seen 1h before, but insufficient notice for gas-fired backup units

INDIA

5 April 2020

- Fall in demand of 31 GW
- Blackout prevented mainly thanks to Hydro and PHS:
 - 8:45pm - 9:10pm: **from 25.5 GW down to 8 GW** to match demand reduction, and **PHS plants turned on pumping** mode
 - 9:10pm - 9:27pm: ramp up **from 8 GW to 19 GW**

PHS installed base evolution



Source: GE Marketing

Installed base to increase by ~50% between 2015-2030.

21st Century ushers in Advanced Pumped Storage Technology

3 GENERATIONS OF TECHNOLOGY

1960s

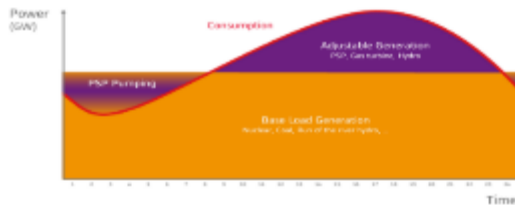
Introduction of reversible pump-turbines



Typical # daily starts and stops

1980s - 2000s

Highest Efficiency (for arbitrage)



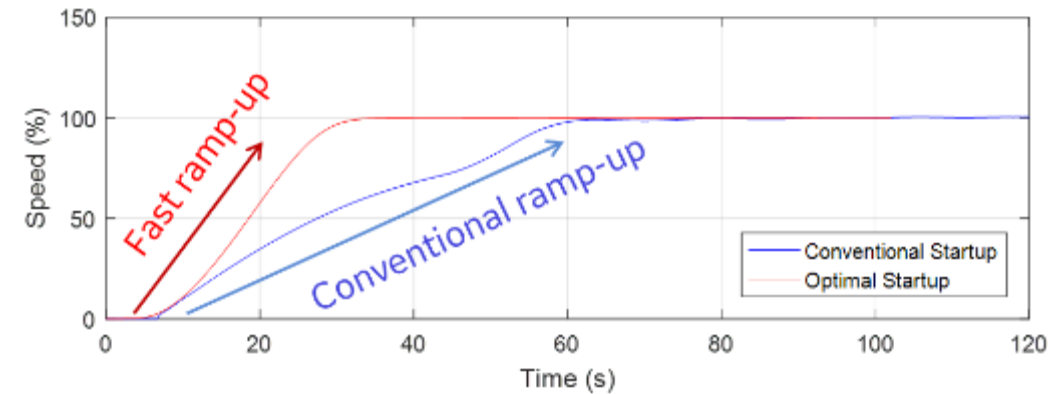
2 to 3

~2015

Flexibility & Reliability



6...
increasing to 10 to 15



- Ramp rates once synchronized 6% per **second**
- **Fast transition** between operating modes
- **Increased flexibility** in generation (turbine) mode
- Variable speed for more **flexibility** in power generation and absorption

Challenges facing PHS development

- **Lack of understanding** about the technology, its capabilities, sustainability profile and innovative new developments – often left out of discussions about energy storage.
- **Difficulty for IPPs in financing** new PSH projects– uncertain revenues from energy arbitrage and many services are not appropriately remunerated.
- **Insufficient incentives** in many markets despite the agreed need for long-duration storage.



Value and Role of Pumped Storage
Hydro under High Variable Renewables

DOE majority-financed study : impact of new PHS on a hypothetical 2028 WECC with 50% wind & solar generation : report out in coming months

Thank you!



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